VOLATILIZATION-FRACTIONATION OF SILICATES RELATED TO CHONDRITE COMPOSITION

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Background

The compositions of chondritic meteorites are linked to the solar composition. It is believed that the chemistry of the (generally) drop-shaped chondrules which comprise a large portion of these meteorites may present valuable clues to their formation and, ultimately, to the early conditions and processes of the planets. A prime candidate mechanism linked to compositional variations in chondrules is vapor fractionation involving either the volatilization of silicate, sulphide, oxide, and metal phases or the reverse processes, condensation from a nebular or stellar gas. Thermodynamic models of these processes exist and, fairly recently, a body of experimental data have been acquired with which to test these and related models of chondrite and planet formation (Mysen et al. 1985).

Experimental Objectives

The purpose of this experiment is to determine the nature of volatilization-fractionation of silicate (and related metallic) compositions related to chondrite compositions. This would be accomplished at ambient (i.e., probably 10^5Pa) pressure at temperatures from 1500°C to 2200°C, at partial pressures of oxygen varying from 10^{-9} to 10^4Pa and as a function of the bulk composition of the silicate starting materials. In addition,

vapor fractionation from individual silicate liquid droplets will be studied as a function of droplet size. The rate of volatilization is expected to be a function of the surface-volume ratio and, therefore, is a function of droplet size. If found, this relationship can in turn be related to conditions required by several models of chondrule formation.

Experimental Conditions in Terrestrial and Space Environments

The minimum temperature at which volatilization of major elements in these systems can effectively be studied is about 1200°C. At these temperatures, such experiments must be carried out at reduced pressure (i.e., around 10^{-1}Pa or lower). In order to achieve significant volatilization rates at atmospheric pressure, temperatures of around 2200°C are required. Volatility of many of the phases of interest is a strong function of oxygen pressure and, consequently fugacity must be controlled within the range from 10^{-9} to 10^{4}Pa. The foregoing conditions can be met rather easily in earthbound experiments. However, one major problem cannot be addressed sufficiently for the purposes of the experiment: the container problem. On Earth it is necessary to place the sample in a container. The problem is that, at the required temperatures, all container materials either react with the samples (e.g., silicates react with ceramics or metals with metallic containers) or they impose their own oxidation conditions on the run (as with tungsten). These major problems are immediately and totally removed in the space environment where a container is unnecessary. Preventing gravitational separation of phases which may have quite different densities is another major problem in the terrestrial environment. It is virtually impossible, for example, to maintain intimate mixture of silicate, metal, and gas phases. This problem, too, would be eliminated under zero or near zero-g conditions.

Experimental Procedure

In pre-launch operations, variously sized (0.1 - 5 mm diameter) glass spheres or sintered pellets of the silicate starting materials will be prepared and inserted into a lazy-susan sample holder. During launch, this holder, containing up to 20 samples, would permit one charge at a time to be levitated. Under relatively high ambient pressures, levitation will be accomplished acoustically; at lower pressures, electrostatic or laser levitation may be used. Samples will be levitated into the pre-heated hotspot in a Mo and W-wound furnace. They will be heated under varying conditions of time (up to 5 minutes at 2200^{o}C and up to 100 hours at 1200^{o}C), oxygen fugacity and temperature (from 1200 to 2200^{o}C). Oxygen fugacity will be controlled by circulation of a self-contained mixture of hydrogen and carbon dioxide modulated by a doped zirconia oxygen ion electrolyte. Temperatures will be controlled and determined to within 5 degrees by thermocouples located in the furnace hotspot. Analytical results will be obtained in two ways: emitted vapors will be analyzed during the runs and quenched run products will be chemically subsequently analyzed. Both quenched droplets and condensed vapor collected on cold plates will be analyzed using a variety of methods including X-ray fluorescence, microprobe, and neutron activation. In situ analyses of the effluent vapor will be carried out using UV/visible/IR absorption and fluorescence spectrometry. In addition, mass spectrometry may be useful.

System Configuration

Operating at the highest temperatures, the furnace may require as much as two kilowatts of power; however, these temperatures, run duration, and thus, peak power consumption, would last only a few (ca. 10) minutes. Insulation should be able to retain the external surface temperature of the furnace at less than 100^{o}C.

It should be possible to maintain the entire furnace assembly including levitator and gas control apparatus to less than four cubic feet. Power supply, temperature control and spectrum analyzer would require some additional space in the vicinity of the furnace. The oxygen fugacity system would require only very small volumes of hydrogen and CO_2 and would, thus, pose no safety hazard.

Mysen, B.E., Virgo, D., and Kushiro, I. (1985). Earth Planet. Sci. Lett.